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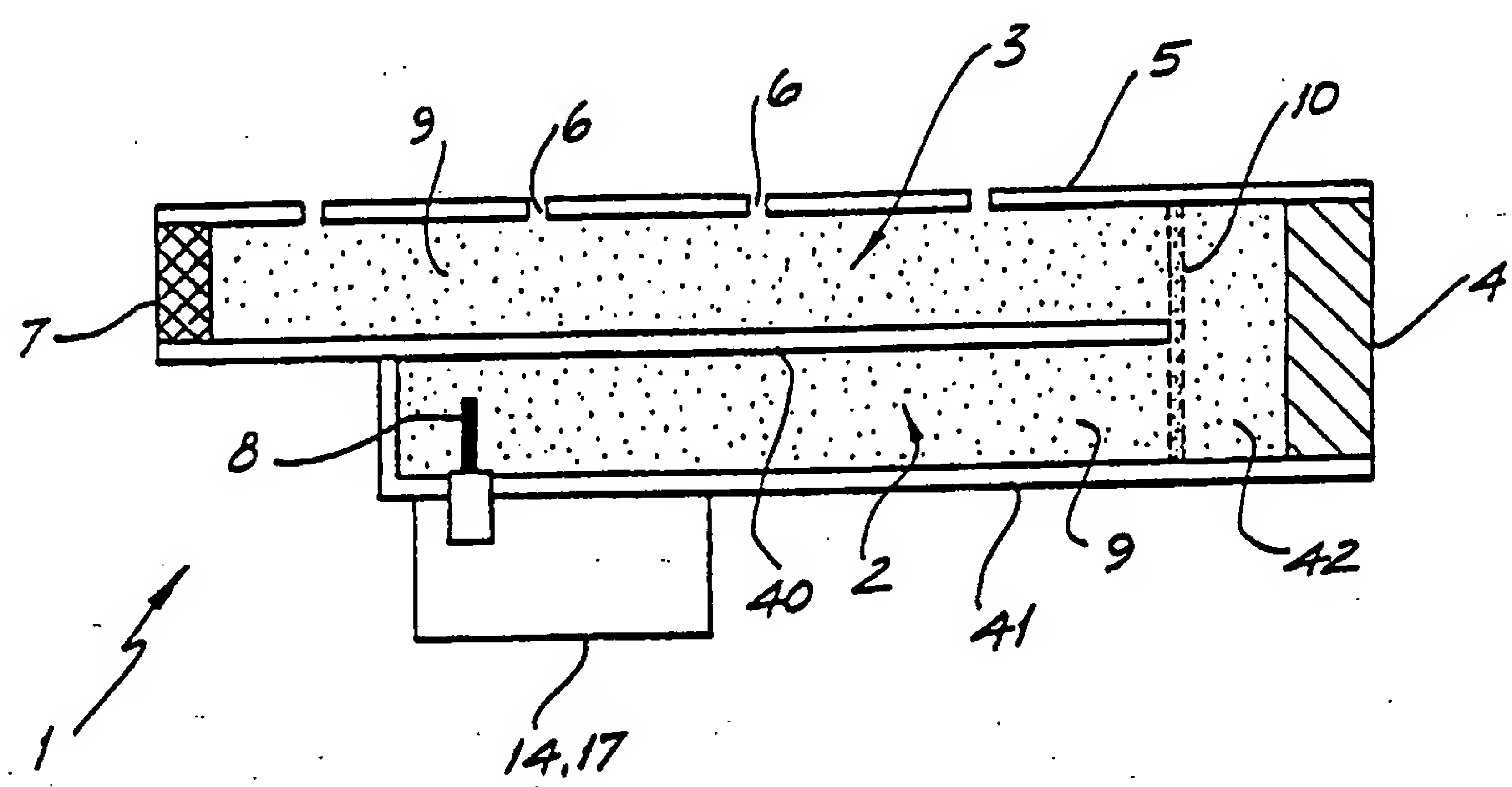

(57) Abstract

A flat plate transmit/receive antenna (1) is disclosed having first and second parallel plate waveguides (2, 3). A waveguide bend (4) communicates energy between the waveguides (2, 3) to enable transmission and reception from an exposed plate (5) of the second waveguide (3) within which an array of apertures (6) is formed. A coupler or probe (8) is provided at a focus of the first waveguide (2) to cause, on transmission, a cylindrical phase front to propagate along the first waveguide (2) which is converted by the waveguide bend (4) to a planar phase front in the second waveguide (3). Scanning and dual polarisation embodiments are also disclosed.

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A FLAT PLATE ANTENNA

Technical Field

The present invention relates to a flat plate transmit/receive antenna, a system for receiving electromagnetic energy, a system for transmitting electromagnetic energy, a system for transmitting and receiving electromagnetic energy, a method for receiving electromagnetic energy, a method for transmitting electromagnetic energy, and a method for transmitting and receiving electromagnetic energy.

Background Art

The present inventor has come to the realisation that there is a need for a two-layer parallel-plate waveguide antenna which transforms a cylindrical phase front in a first parallel plate waveguide to a plane phase front in an associated transmission/receiving waveguide since such an antenna has a number of desirable characteristics which make it particularly useful for domestic satellite communications.

Objects of the Invention

It is an object of the present invention to provide a flat plate transmit/receive antenna.

Other objects include providing a system for receiving electromagnetic energy, a system for transmitting electromagnetic energy, a system for transmitting and receiving electromagnetic energy, a method for receiving electromagnetic energy, a method for transmitting electromagnetic energy, and a method for transmitting and receiving electromagnetic energy.

Disclosure of the Invention

In accordance with a first embodiment of the present invention there is disclosed a flat plate transmit/receive antenna comprising:

a first parallel plate waveguide;

a second parallel plate waveguide;

a coupler for coupling energy into and out of the first waveguide;

a waveguide bend for communicating energy between the first and second parallel plate waveguides and providing a transformation between a cylindrical phase front in the first waveguide and a planar phase front in the second waveguide;

a transmit/receive plate comprising one plate of the second waveguide and having an array of apertures for coupling electromagnetic energy between the second waveguide and free space; wherein

the apertures are spaced from each other such that electromagnetic energy between the second waveguide and free space is coupled to provide a

selected phase of electromagnetic energy transmitted by the transmit/receive plate into free space.

Generally, the selected phase is either:

(1) substantially in phase, to produce a beam perpendicular to the transmit/receive plate; or

(2) with a linear gradient, to produce a beam at a small angle to the perpendicular.

In accordance with a second embodiment of the present invention there is disclosed a system for receiving electromagnetic energy, the system comprising:

a flat plate transmit/receive antenna of the first embodiment for receiving the electromagnetic energy from free space and outputting a received signal;

a receiver operatively associated with the coupler of the antenna.

Typically, the receiver includes a filter and amplifier connected to the antenna to filter and amplify the received signal and a demodulator connected to the filter and amplifier for demodulating the received signal to provide an output information signal.

In accordance with a third embodiment of the present invention there is disclosed a system for transmitting electromagnetic energy, the system comprising:

a flat plate transmit/receive antenna of the first embodiment for transmitting electromagnetic energy into free space;

a transmitter operatively associated with the coupler of the antenna.

Generally, the transmitter of the third embodiment includes a microwave frequency generator, a modulator for mixing the microwave frequency with an input information signal to produce a modulated signal and a power amplifier for amplifying the modulated signal and outputting it to a transmit/receive antenna of the first embodiment for transmission of the modulation signal to free space.

In accordance with a fourth embodiment of the present invention, there is disclosed a system for transmitting and receiving electromagnetic energy, said system comprising:

a flat plate transmit/receive antenna of the first embodiment for receiving and outputting a received signal from free space and for transmitting electromagnetic energy into free space;

a receiver operatively associated with the coupler of antenna; and

a transmitter operatively associated with the coupler of the antenna.

Generally, in the system of the fourth embodiment the antenna is coupled to a circulator, the circulator transferring energy received by the antenna to a filter, amplifier and receiver to provide an output information signal. The circulator also transfers energy from a frequency generator, modulator and power amplifier to the antenna for transmission of the modulated input information signal to free space.

In accordance with a fifth embodiment of the present invention there is disclosed a method for receiving electromagnetic energy, said method comprising the step of receiving the energy with a system of the second embodiment.

In accordance with a sixth embodiment of the present invention there is disclosed a method for transmitting electromagnetic energy, the method comprising applying an information input signal to the transmitter of the system of the third embodiment.

In accordance with a seventh embodiment of the present invention there is disclosed a method for transmitting and receiving electromagnetic energy, the method comprising:

applying an information input signal to the transmitter of the system of the fourth embodiment;

receiving the energy with a system of the fourth embodiment.

Generally the first and second parallel plate waveguides are disposed adjacent to one another in a sandwich type arrangement. This is preferably achieved using a single common plate between each of the waveguides.

It is also preferred that the antenna be operated within the range of about 5 GHz to about 60 GHz

Examples of preferred couplers are coaxially coupled top-loaded monopole and dielectrically loaded monopole.

Generally the waveguide bend is a metal or metals which form a common substantially U-shaped wall at one end of the first and second parallel plate waveguides with an aperture adjacent the common wall and communicating energy between each of the waveguides. Alternatively, the transmit/receive plate may can also be manufactured using printed circuit techniques to provide a dielectric sheet with a metallic bonded coating, with the required slots having been etched into the metal layer.

The metals from which the waveguides, parabolic bend and transmit/receive plate are preferably copper, brass or aluminium.

The apertures in the transmit/receive plate are typically rectangular

slots arranged transverse the direction of wave propagation in the second parallel plate waveguide. Any other orientation, except parallel to the direction of propagation, is also useful. Other slot shapes can be used to provide circular or elliptical polarisations, such as a crossed slot for example.

The dimensions of the slots determines the characteristics of the beam. Also the spacing between the slots determines the displacement of undesirable grating lobes and as such it is preferred that the slot centres be spaced by the wavelength (λ) in the plane of the wave in the second waveguide and spaced by a value less than or equal to λ, and most preferably about 0.8λ in the direction of wave propagation in the second waveguide.

For a slot spacing of less than λ in the direction of wave propagation, it is preferred to fill the waveguides with a dielectric.

It is preferred to fill the waveguides with a dielectric such as a doped foam (such dielectrics are available commercially eg from Emerson & Cumming).

To transfer from a cylindrical wave in a lower parallel plate waveguide to a plane wave in an upper parallel plate waveguide requires a parallel bend with focus on the input probe. The shape may be varied from parabolic for purposes of obtaining a shaped, non-focussed beam.

Brief Description of the Drawings

A number of embodiments of the present invention will now be described with reference to the drawings in which:

Fig. 1 is an isometric view of the external structure of an antenna of the preferred embodiment;

Fig. 2 is a top plan view of the antenna of Fig. 1 illustrating the arrangement of the slots in the upper waveguide;

Fig. 3 is a vertical cross-section of section III-III of Fig. 2;

Fig. 4 illustrates a transmitting/receiving system coupled to the antenna of the preferred embodiment;

Fig. 5 illustrates the various arrangement of grating lobes;

Fig. 6 illustrates an alternative embodiment that enables a transmit/receive lobe to be scanned;

Fig. 7 illustrates a further embodiment of a dual polarisation antenna;

Figs. 8 and 9 illustrate systems for receiving and transmitting information signals; and

Figs. 10A-C show examples of apertures that can be used to obtain different polarisations.

Best and Other Modes for Carrying Out the Invention

Generally illustrated in Fig. 1 is a flat plate antenna 1 comprising a lower parallel plate waveguide 2 connected to an upper parallel plate waveguide 3 by a parabolic waveguide bend 4.

Referring to Figs. 2 and 3, the flat plate antenna 1 is shown in greater detail. The upper waveguide 3 is formed by a transmit/receive plate 5 and a common plate 40. The transmit/receive plate 5 comprises an array of slots 6 adapted to couple energy between waveguide 3 and free space. The upper waveguide 3 ends in a microwave absorber 7 that prevents energy being reflected from the end of the waveguide 3.

The lower waveguide 2 is formed between the common plate 40 and a base plate 41. As seen in plan in Fig. 2, the waveguide 2 is preferably substantially conical to achieve focussing on the bend 4. Energy is coupled into and out of the lower waveguide 2 via probe 8.

The parabolic waveguide bend 4 is substantially U-shaped and connects the transmit/receive plate 5 with the base plate 41 to provide an aperture 42 that communicates between the adjacent ends of the waveguides 2 and 3. The bend 4 acts to redirect the waves in the waveguides 2 and 3 through a physical 180°, by a 360° change in phase. The bend 4 also transforms the plane of waveform propagation between the waveguides 2 and 3.

The operation of the antenna 1 is best described in transmission, although it will be understood by those skilled in the art that a reverse operation occurs when operating in reception.

On transmission, energy is provided to the probe 8 which creates an electromagnetic wave in the lower waveguide 2. The wave travels down the waveguide 2 towards the bend 4 which transfers the wave into the upper waveguide 3. The waveguide bend 4, has a parabolic profile in the plane of the waveguides 2 and 3, and thus provides a focusing action which causes a planar wave to propagate in the upper waveguide 3. The transmit/receive plate 5 and the array of slots 6 arranged therein allow the wave to radiate in a direction substantially perpendicular to the plane of the surface of the plate 5. This is achieved by the planar wave reaching each slot in-phase thus affording maximum directional gain. For perpendicular propagation to be successfully achieved, two conditions must be met.

Firstly, the upper waveguide 3 must be a slow wave structure, for example by appropriate dielectric loading, such that each of the slots 6 are fed in phase or by a phase difference equal to a multiple of 2π radians. Dielectric 9 in each of the waveguides 2 and 3 is shown in Fig. 3 to achieve this operation.

Secondly, the spacing between each of the slots must be sufficiently small to avoid the production of grating lobes, that are known in the art. Also, the size of individual slots will, in general, vary over the surface of the plate 5 in order to maximise efficiency with a phase appropriate to the type of beam desired. For example, in-phase for a substantially perpendicular beam affording maximum directional gain.

For example, as shown in Fig. 2, one preferred embodiment for a perpendicular beam uses a spacing d between the slots 6 of 0.8λ that adequately suppresses grating lobes. If the upper waveguide 3 of the antenna 1 is completely filled with dielectric 9 of a dielectric constant 1.56 then adjacent slots in the direction of propagation (d) will have a 2π phase difference, whilst slots in the transverse direction, separated by distance $s = \lambda$ will be in phase. This results in a radiated beam perpendicular to the plane of the antenna 1.

Also shown in Fig. 3 is a dielectric matching layer 10 which improves the operation of the waveguide bend 4.

The antenna 1 is useful for transmitting and receiving frequencies between about 5 GHz and about 60 GHz with the preferred embodiments adapted specifically to the AUSSAT satellite system which transmits between 14 and 14.5 Ghz and receives between 12 and 12.5 GHz. The frequency band of signals determines the overall size of the antenna.

Illustrated in Fig. 4 is a transceiver 11 coupled to the antenna 1 by a circulator 12. The circulator 12 couples energy between the antenna 1 and the power amplifier 13 on the transmitting side and the bandpass filter 14 on the receiving side. When transmitting, microwave frequency generator 15 creates a microwave frequency which is coupled to modulator 16 and modulated by an information input signal fed into modulator 16. The modulated signal is amplified by a power amplifier 13 and outputted to the antenna 1 via the circulator 12. On reception, energy is coupled into the antenna 1 and directed via the circulator 12 to the bandpass filter 14. It is then coupled into a low noise amplifier 17 and then to receive circuit 18 which in turn outputs a demodulated information signal which is fed into an appropriate output device.

In a preferred embodiment adapted for a receive antenna, the bandpass filter 14 and low noise amplifier 17 are located on the antenna immediately adjacent the probe 8 as indicated in Fig. 3.

Fig. 5 illustrates the transmission and formation of grating lobes in the flat plate antenna 1. The antenna 1 creates a main beam 19 substantially perpendicular to the plane of the antenna. For an antenna arrangement where the slots 6 are spaced at multiples of the wavelength, grating lobes 20 perpendicular to the main beam 19 form in the plane of the antenna 1, reducing the efficiency of the antenna and causing interference. It is advantageous therefore if the grating lobes can be suppressed. Also illustrated in Fig. 5, are grating lobes 21 of a preferred embodiment that uses a spacing of $d = 0.8\lambda$ between the slots 6. In this embodiment the grating lobes are suppressed as is well known to those skilled in the art.

For spacings less than the wavelength, it is necessary for the propagation of the wave within the waveguides to be slowed by means of a dielectric 9. One preferred dielectric is a loaded foam doped with a high dielectric material or metal, to provide an overall a dielectric constant approximately 1.56, for a spacing $d = 0.8\lambda$. An equation for the determination of the dielectric constant is as follows:

$$\varepsilon_r = \frac{n\lambda}{d}$$

It will be noted that a dielectric is not required if $d = \lambda$.

Fig. 6 illustrates a another flat plate antenna 22 which has a number of probes 8 arranged about the focus of the lower parallel plate waveguide 23. The waveguide 23 is coupled into an upper waveguide 24 via a parabolic waveguide bend 25 as previously described. The arrangement of the probes 8 in Fig. 6 allows multiple main beams to be produced by the antenna in a plane transverse to the propagation of the wave in the upper waveguide 24. Such an arrangement will provide for the antenna 22 to be able to transmit and/or receive from more than one satellite substantially simultaneously.

Fig. 7 illustrates an embodiment of a dual polarisation antenna 26. The antenna 26 has two separate lower parallel plate waveguides 27 and 28 that respectively couple via waveguide bends 29 and 30 to a common upper parallel plate waveguide 31. The upper waveguide 31 has a transmit/receive plate with two arrays of slots 32 and 33 adapted for transmission/reception of waves into and out of the respective lower waveguides 27 and 28.

It will be understood by those skilled in the art that the arrangement illustrated in Fig. 7 can at least double the communication volume handled by the antenna 26.

Figs 8 and 9 illustrate respectively systems for receiving and transmitting information signals. The components of each system is the same as that earlier described with respect to Fig. 4.

The rectangular slots described above are particularly useful for obtaining linear polarisation. However, any orientation except parallel to the direction of propagation will suffice. The apertures shown in Figs. 10A-C provide various polarisations and are each preferably arranged at an angle of 45^{O} to the direction of propagation of the wave in the second waveguide. Fig. 10A shows a crossed slot or cruciform shape that provides circular polarisation. The elliptoid of Fig. 10b and notched circle of Fig. 10C are also useful.

Industrial Applicability

A flat plate antenna in accordance with the present invention is particularly useful in systems for transmitting and/or receiving satellite communication signals.

The foregoing describes only a number of embodiments of the present invention and other embodiments, obvious to those skilled in the art can be made thereto without departing from the scope of the present invention. For example, the lower waveguide 2 of Fig. 2 can be rectangular in shape rather than substantially conical.

CLAIMS:

1. A flat plate transmit/receive antenna comprising:

a first parallel plate waveguide;

a second parallel plate waveguide;

a coupler for coupling energy into and out of the first waveguide;

a waveguide bend for communicating energy between the first and second parallel plate waveguides and providing a transformation between a cylindrical phase front in the first waveguide and a planar phase front in the second waveguide;

a transmit/receive plate comprising one plate of the second waveguide and having an array of apertures for coupling electromagnetic energy between the second waveguide and free space; wherein

the apertures are spaced from each other such that electromagnetic energy between the second waveguide and free space is coupled to provide a selected phase of electromagnetic energy transmitted by the transmit/receive plate into free space.

2. A flat plate transmit/receive antenna as claimed in claim 1 wherein the selected phase is substantially in phase.

3. A flat plate antenna as claimed in claim 1 wherein the first and second parallel plate waveguides are disposed adjacent to one another in a sandwich type arrangement.

4. A flat plate antenna as claimed in claim 3 wherein a single common plate is disposed between and divides the waveguides.

5. A flat plate antenna as claimed in claim 1 wherein said antenna is operable over the range of about 5 GHz to about 60 GHz

6. A flat plate antenna as claimed in claim 1 wherein said waveguide bend is a metal or metals which form a common substantially U-shaped wall at one end of the first and second parallel plate waveguides with an aperture communicating energy between each of the waveguides.

7. A flat plate antenna as claimed in claim 1 wherein said waveguides, parabolic bend and transmit/receive plate are formed of materials selected from the group consisting of copper, brass and aluminium.

8. A flat plate antenna as claimed in claim 1 wherein said apertures are rectangular slots arranged transverse the direction of wave propagation in the second parallel plate waveguide.

9. A flat plate antenna as claimed in claim 8 wherein said slots have slot centres that are spaced by one wavelength (λ) in the plane of the wave in the second waveguide and spaced by a value less than or equal to λ, in the direction of wave propagation in the second waveguide.

10. A flat plate antenna as claimed in claim 9 wherein said value less than λ is about 0.8λ.

11. A flat plate antenna as claimed in claim 9 or 10 wherein for a slot spacing of less than λ in the direction of wave propagation, a dielectric is provided in the waveguides.

12. A flat plate antenna as claimed in claim 11 wherein said dielectric fills said waveguides.

13. A flat plate antenna as claimed in claim 6 wherein said waveguides are divided by a single common wall adjacent said aperture.

14. A flat plate antenna as claimed in claim 6 wherein said waveguide bend is a parallel bend focussed on said coupler.

15. A flat plate antenna as claimed in claim 1 wherein said coupler comprises a plurality of coupling elements for enabling scanning of transmitted and/or received energy.

16. A flat plate antenna as claimed in claim 1 wherein said first parallel plate waveguide is divided into two adjacent sub-waveguides each having a corresponding coupler, said sub-waveguides each communicating energy therefrom to said second parallel plate waveguide via corresponding waveguide bends, said transmit/receive plate having two arrays of apertures for respectively coupling electromagnetic energy between the second waveguide and free space.

17. A flat plate antenna as claimed in claim 16 wherein said waveguide bends and said arrays are displaced by 90° so as to permit dual polarization operation of said antenna.

18. A flat plate antenna as claimed in claim 1 wherein said coupler is selected from the group consisting of a coaxially coupled top-loaded monopole and dielectrically loaded monopole.

19. A system for receiving electromagnetic energy, the system comprising:

a flat plate transmit/receive antenna as claimed in claim 1 for receiving the electromagnetic energy from free space and outputting a received signal;

a receiver operatively associated with the coupler of the antenna.

20. A system as claimed in claim 19 wherein the receiver includes a filter and amplifier connected to the antenna to filter and amplify the received signal and a demodulator connected to the filter and amplifier for demodulating the received signal to provide an output information signal.

21. A system for transmitting electromagnetic energy, the system comprising:

a flat plate transmit/receive antenna as claimed in claim 1 for transmitting electromagnetic energy into free space;

a transmitter operatively associated with the coupler of the antenna.

22. A system as claimed in claim 21 wherein the transmitter includes a microwave frequency generator, a modulator for mixing the microwave frequency with an input information signal to produce a modulated signal and a power amplifier for amplifying the modulated signal and outputting it to a transmit/receive antenna for transmission of the modulation signal to free space.

23. A system for transmitting and receiving electromagnetic energy, said system comprising:

a flat plate transmit/receive antenna as claimed in claim 1 for receiving and outputting a received signal from free space and for transmitting electromagnetic energy into free space;

a receiver operatively associated with the coupler of antenna; and

a transmitter operatively associated with the coupler of the antenna.

24. A system as claimed in claim 23 wherein the antenna is coupled to a circulator, the circulator transferring energy received by the antenna to a filter and amplifier included in said receiver to provide an output information signal, said circulator also transferring energy from a frequency generator, modulator and power amplifier of said transmitter to the antenna for transmission of a modulated input information signal to free space.

25. A method for receiving electromagnetic energy, said method comprising the step of receiving the energy with a system as claimed in claim 19.

26. A method for transmitting electromagnetic energy, said method comprising the step of applying an information input signal to the transmitter of the system as claimed in claim 21.

27. A method for transmitting and receiving electromagnetic energy, the method comprising:

applying an information input signal to the transmitter of the system claimed in claim 23; and

receiving the energy with a receiver system claimed in claim 23.

28. A flat plate antenna as claimed in claim 1 wherein the selected phase substantially possesses a linear phase gradient.

29 A flat plate antenna as claimed in claim 1 wherein said transmit/receive plate is manufactured using printed circuit techniques.

30. A flat plate antenna as claimed in claim 29 wherein said transmit/receive plate comprises a dielectric sheet with metallic bonded coating, said apertures having been etched into said metallic coating.

31. A flat plate antenna as claimed in claim 1 wherein said apertures are elliptical in shape to provide elliptical polarisation of the transmitted energy.

32. A flat plate antenna as claimed in claim 31 wherein said apertures are circular to provide circular polarisation.

33. A flat plate antenna as claimed in claim 32 wherein said apertures are notched.

34. A flat plate antenna as claimed in claim 1 wherein said apertures are cruciform in shape to provide elliptical polarisation of the transmitted energy.

35. A flat plate antenna as claimed in claim 31 or 34 wherein said apertures are arranged at an angle of about 45° from the direction of propagation of the wave in the second waveguide.

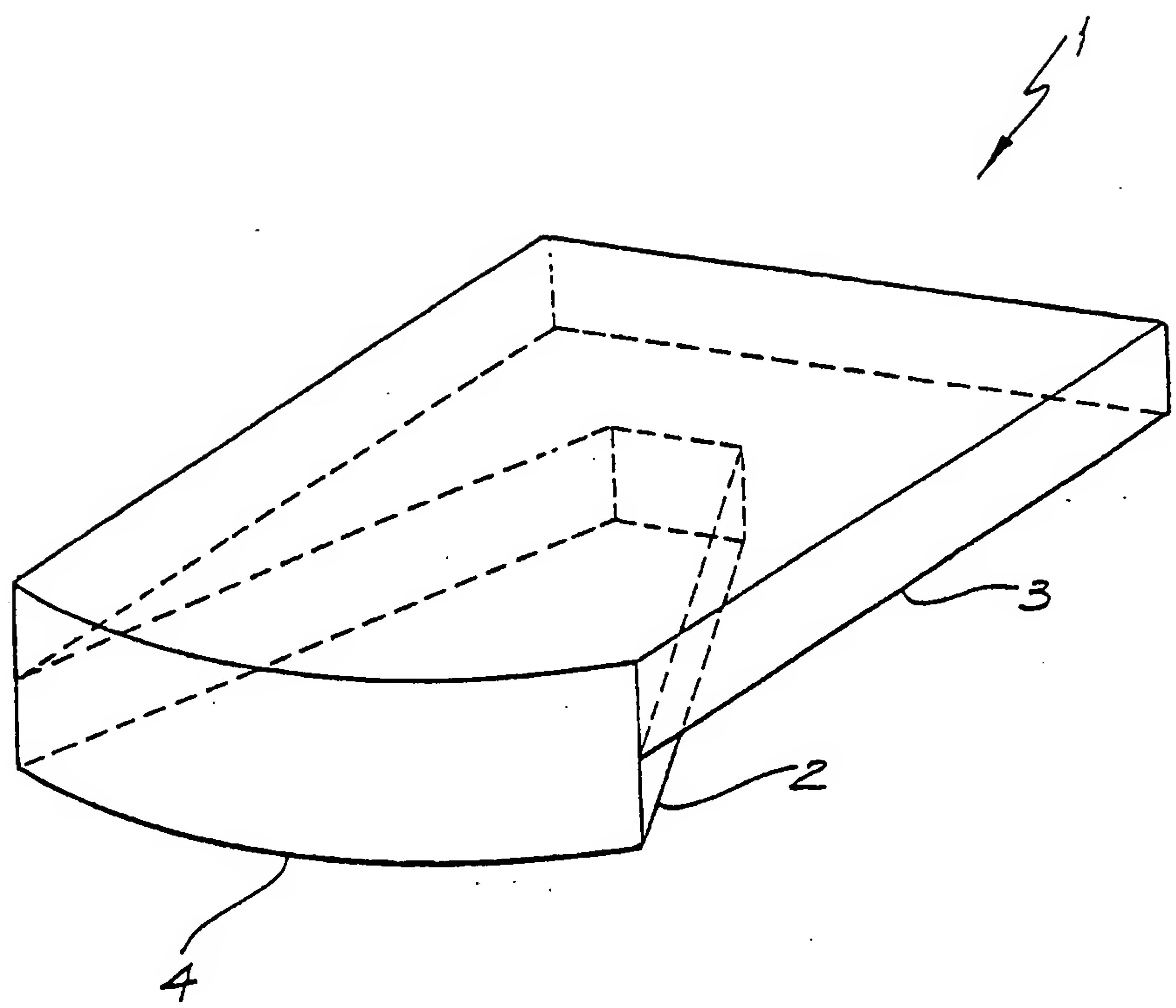


FIG. 1

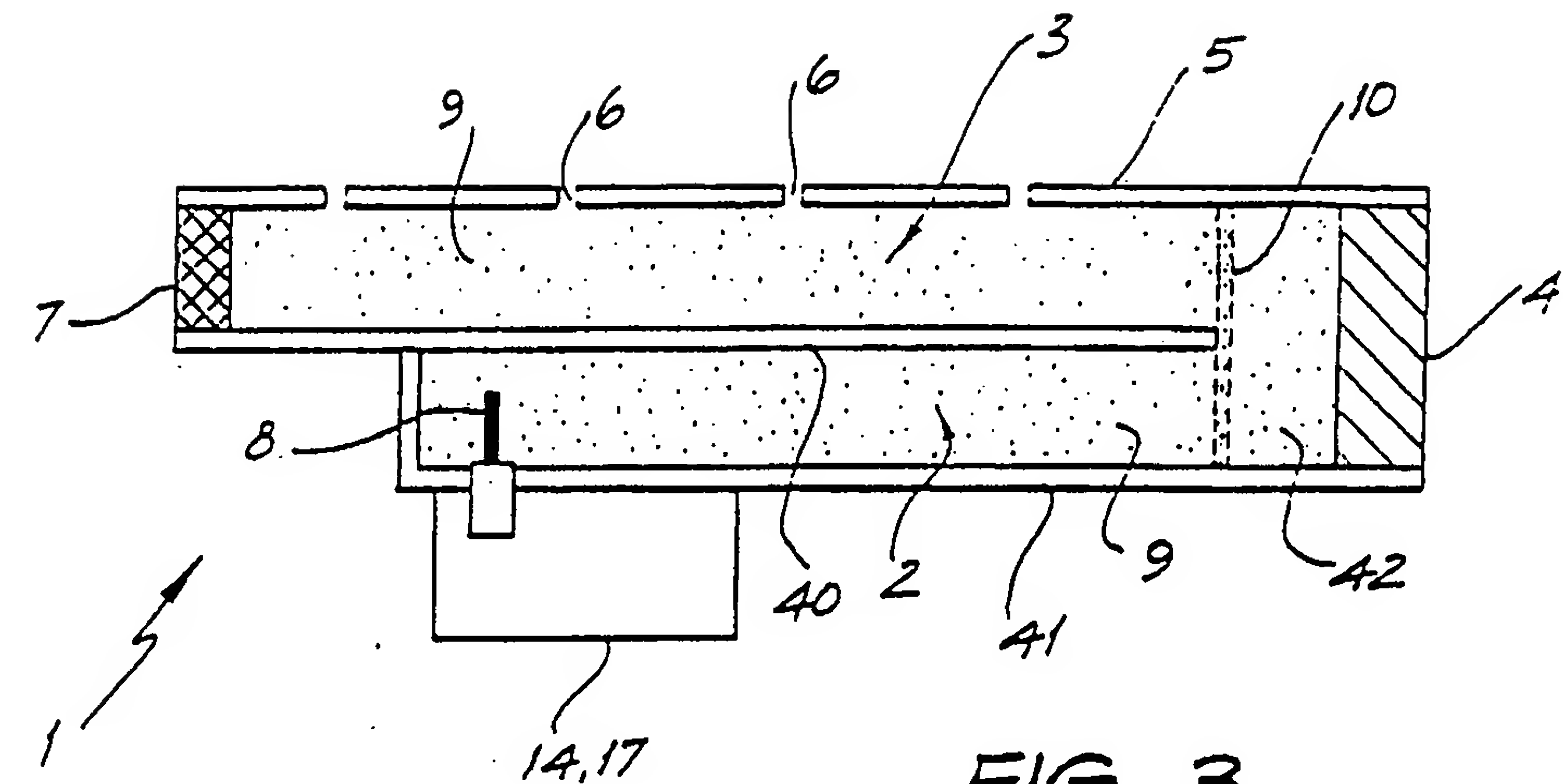


FIG. 3

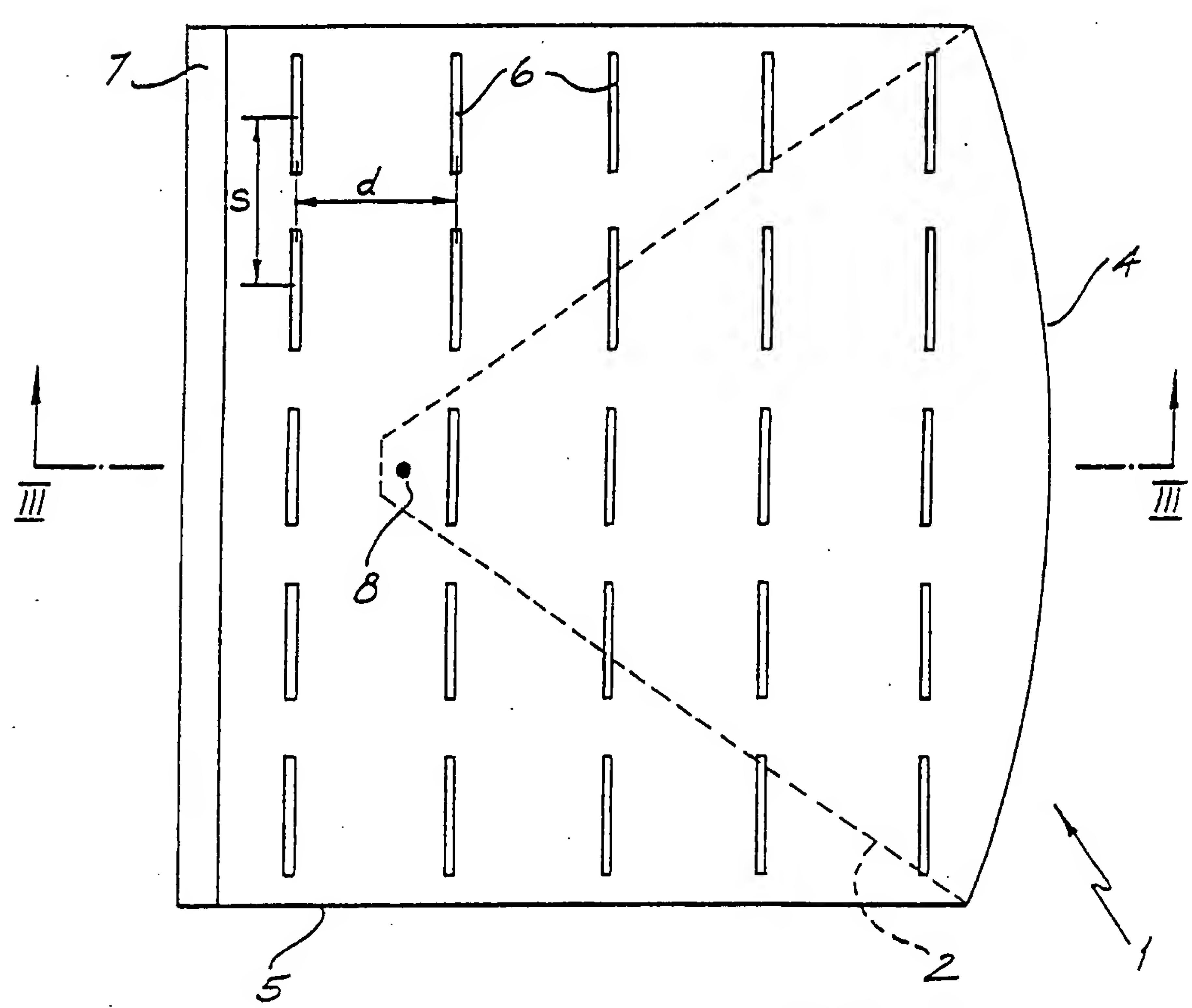
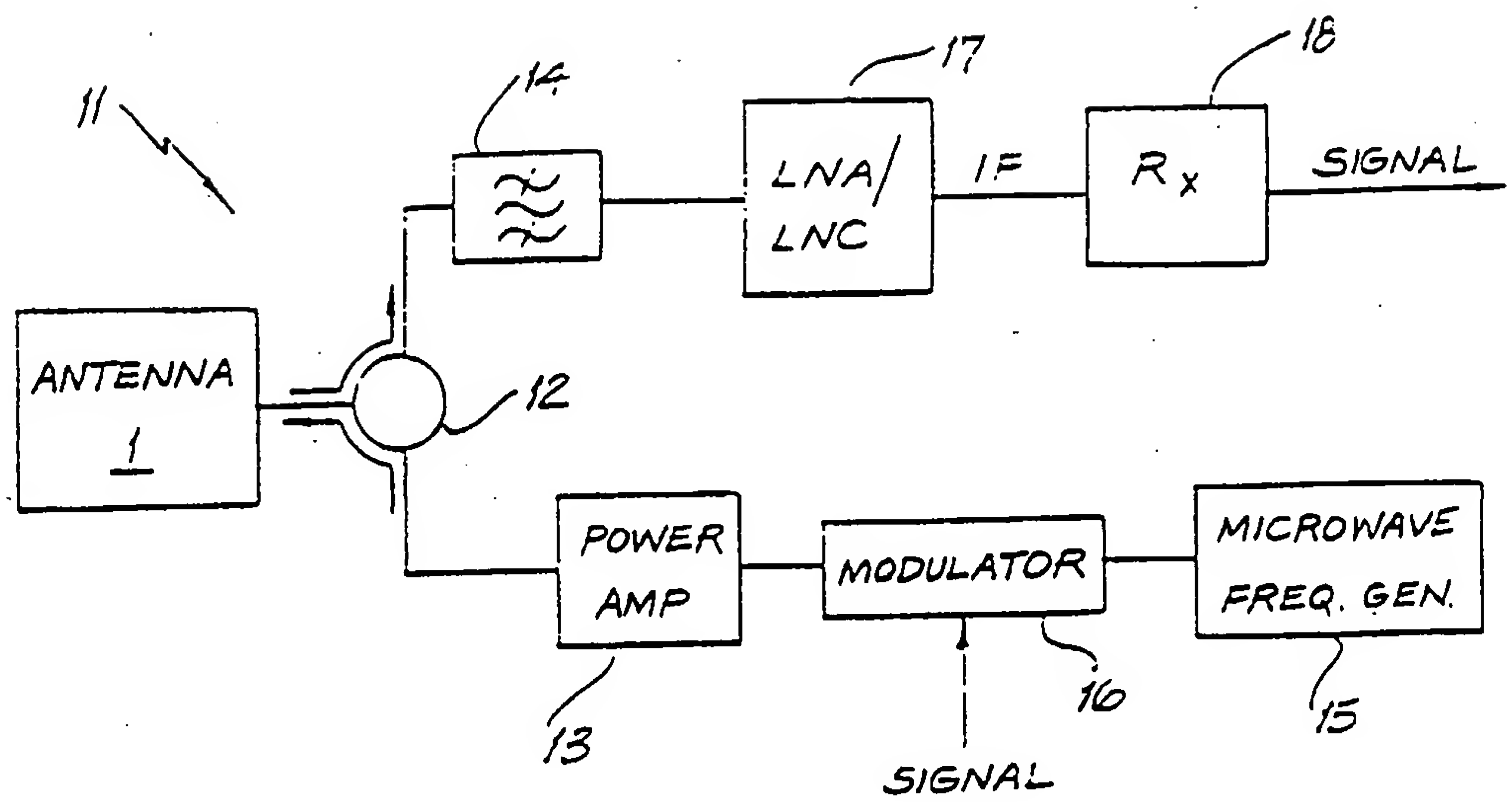


FIG. 2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15
SIGNAL

FIG. 4

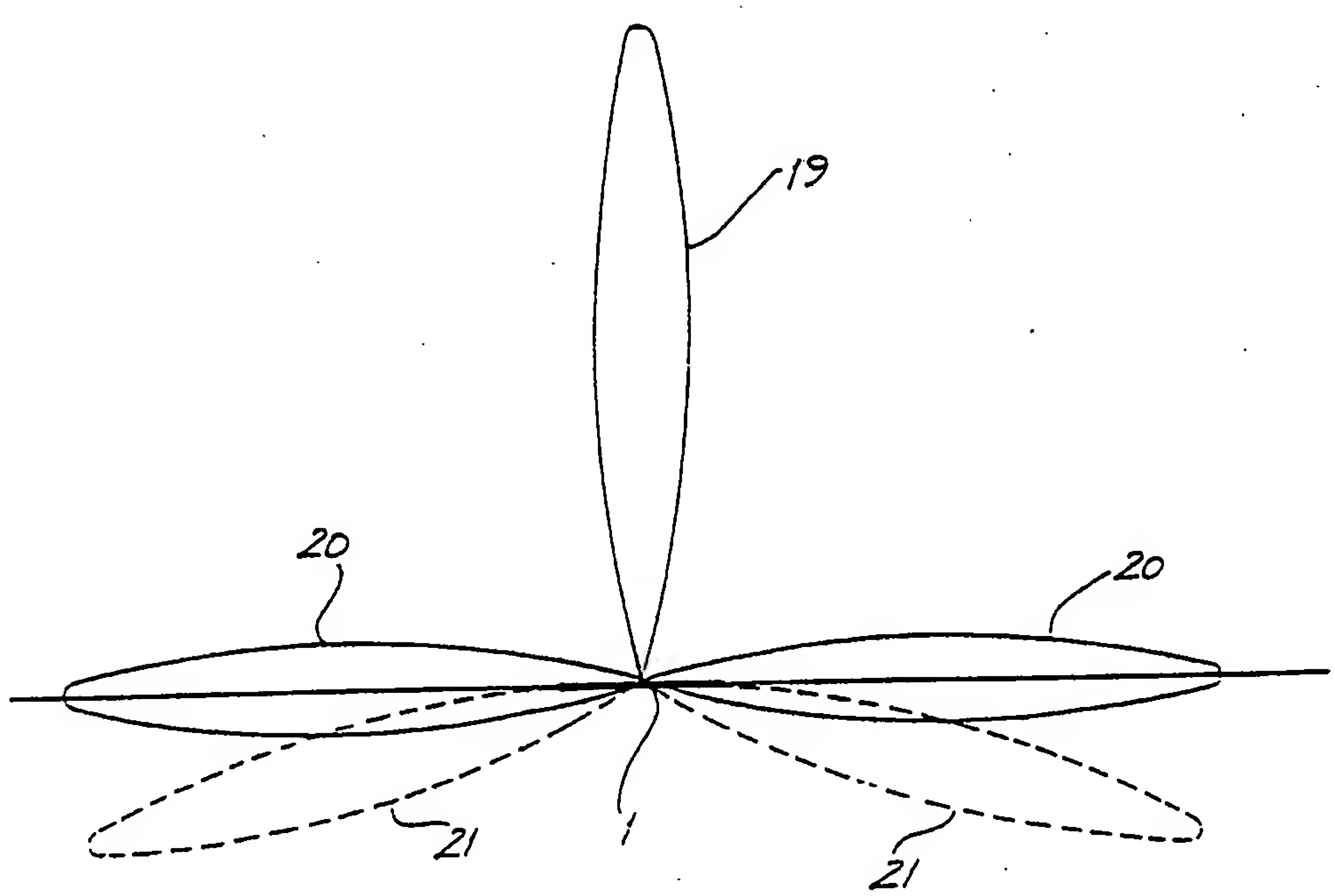
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FIG. 5

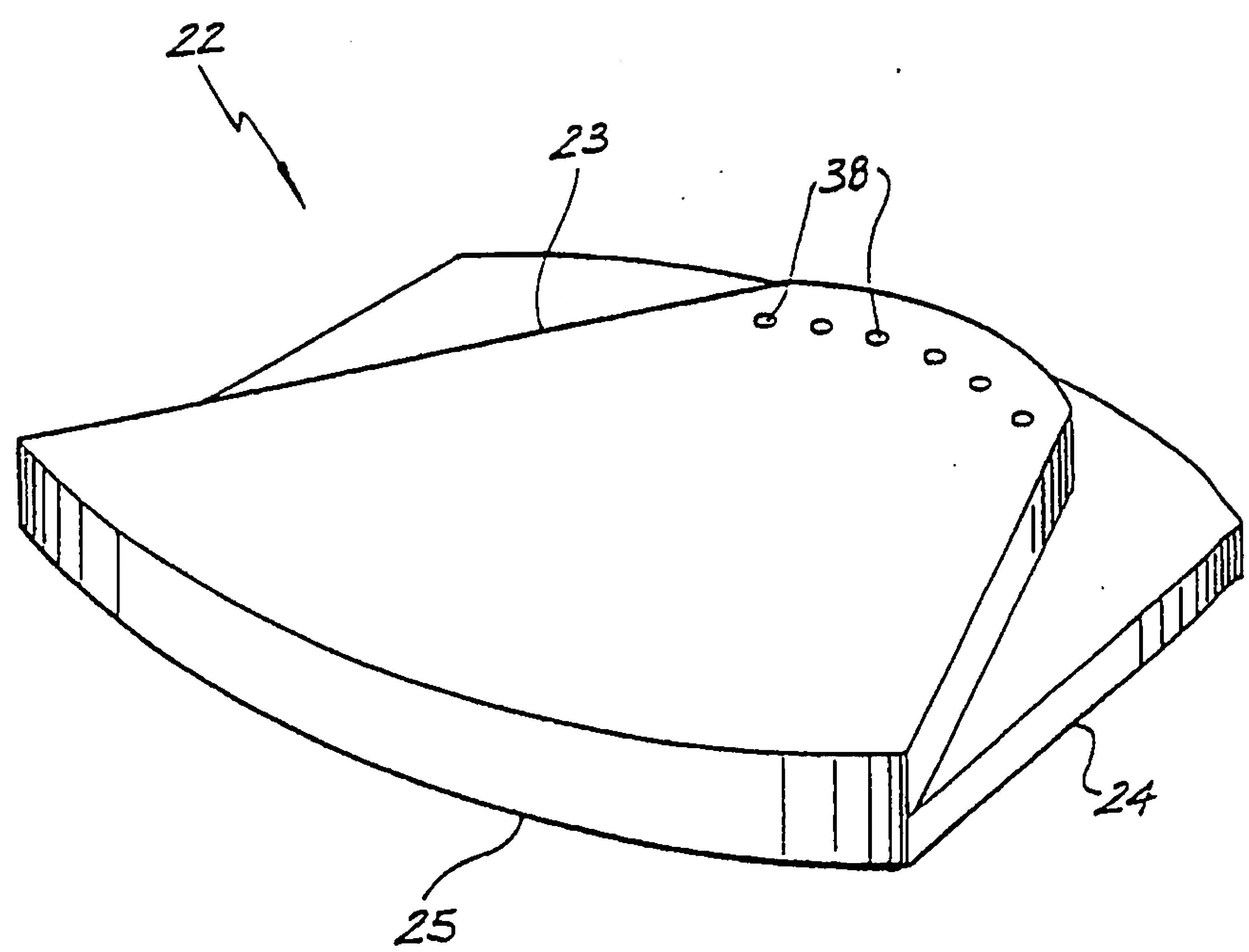

FIG. 6

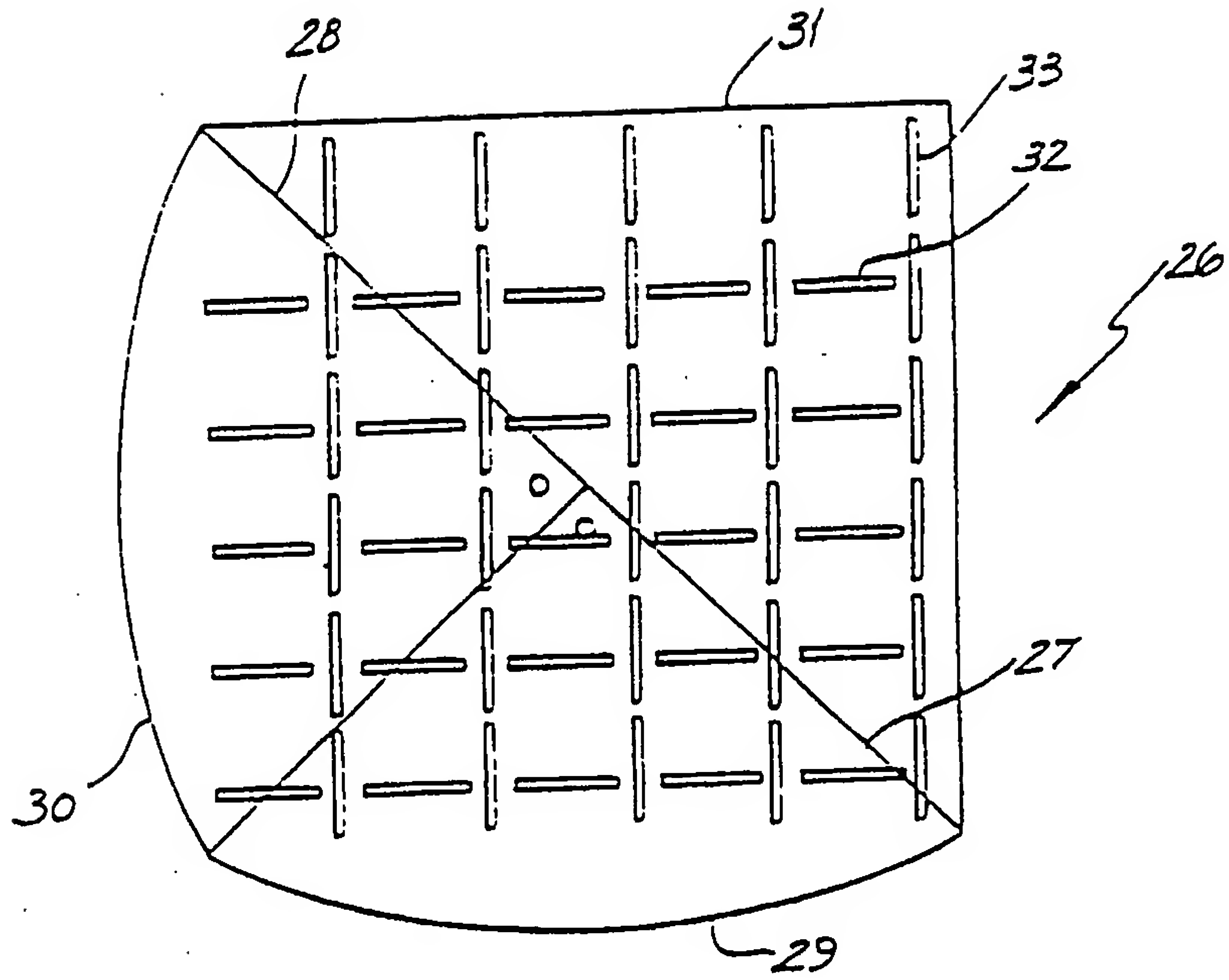

FIG. 7

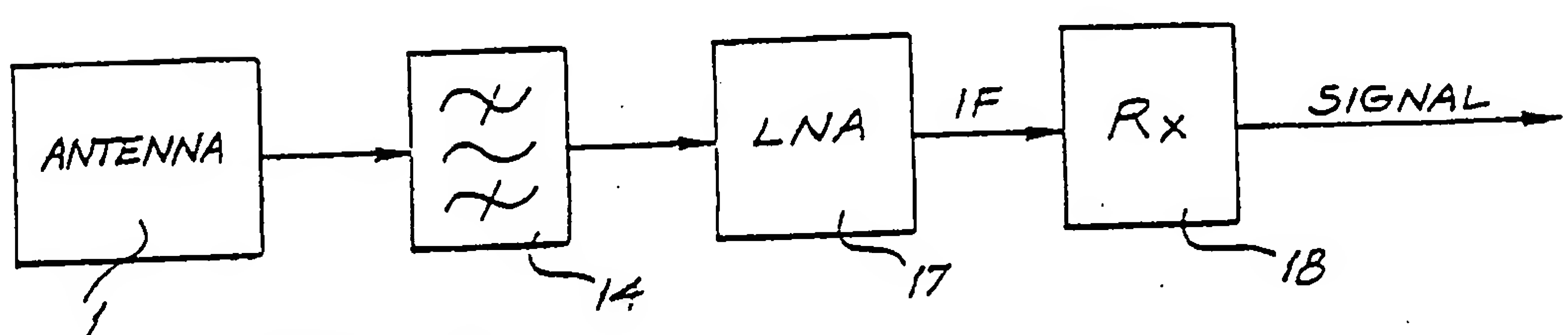

FIG. 8

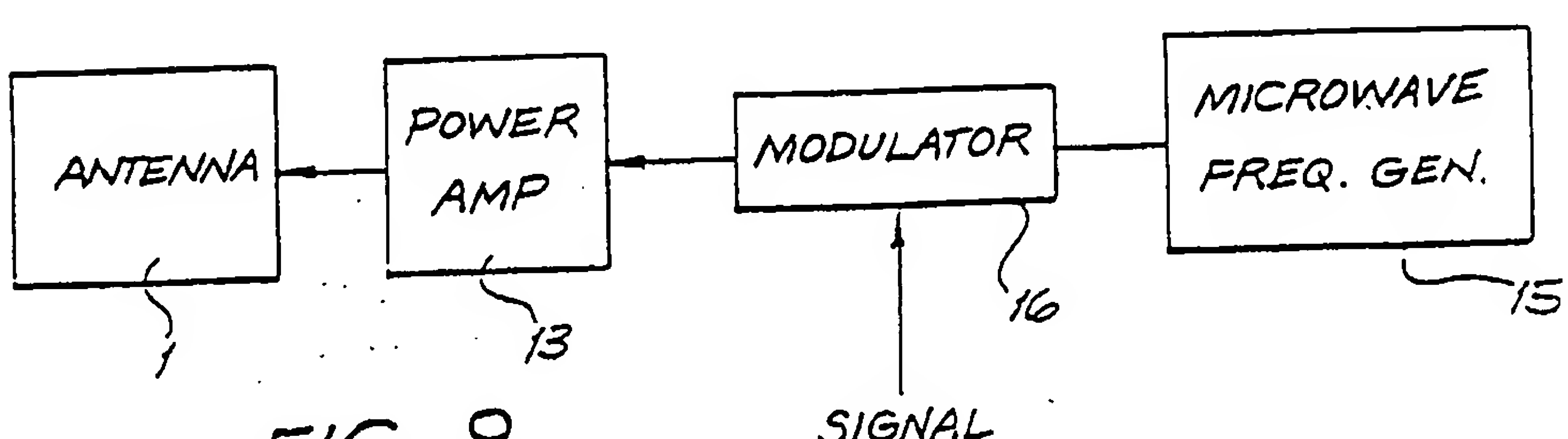

FIG. 9

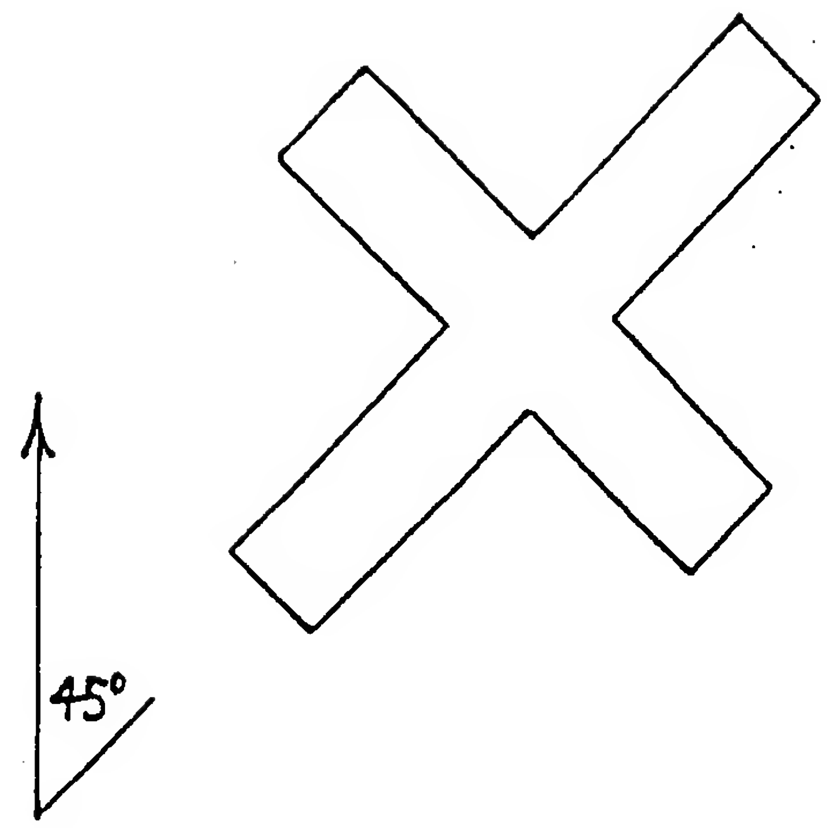

FIG. 10A

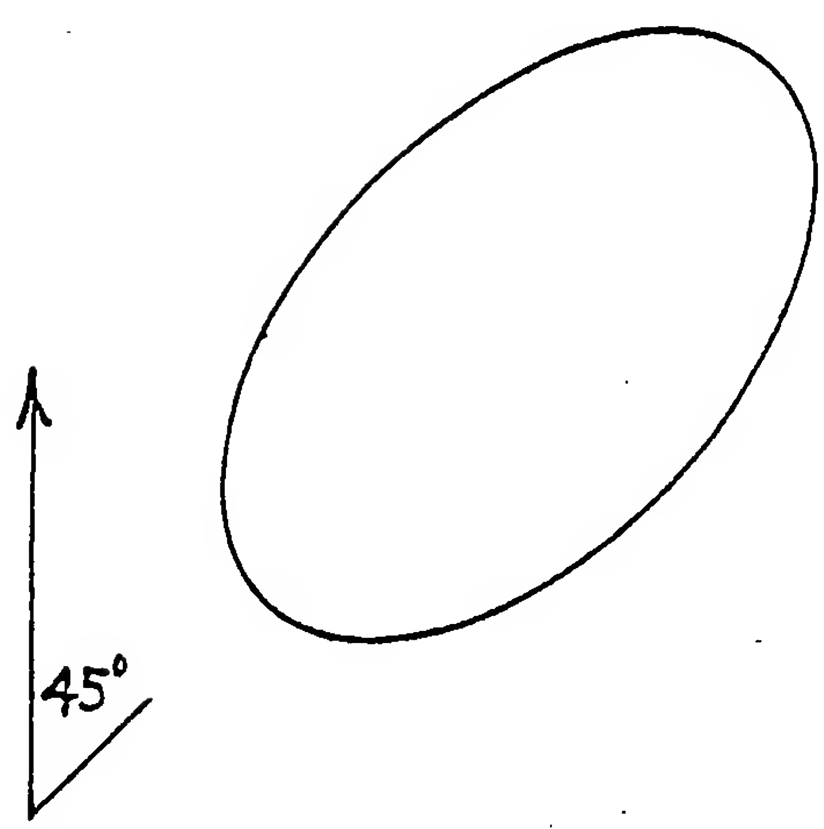

FIG. 10B

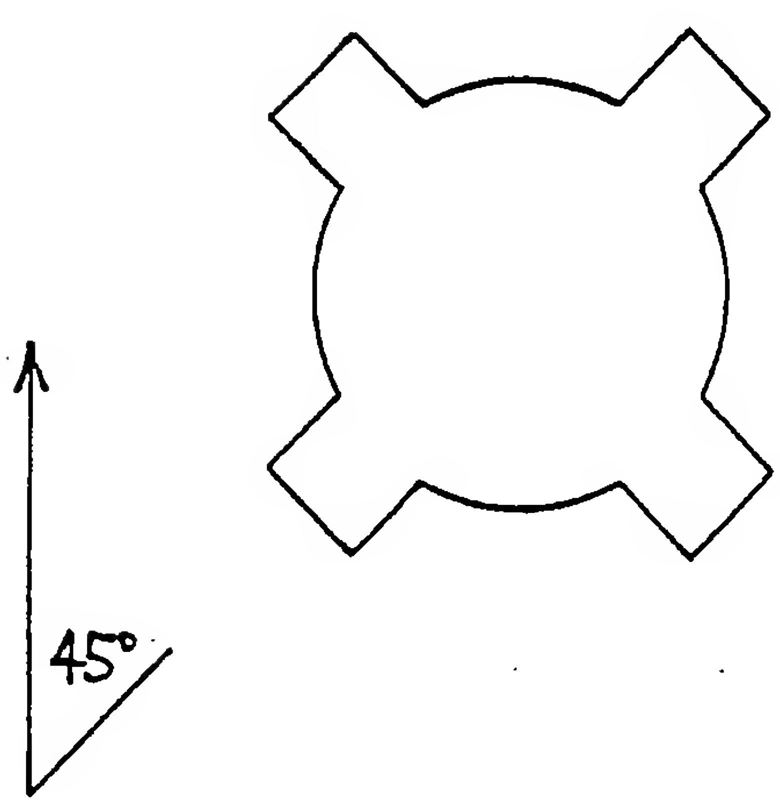

FIG. 10C

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 91/00165

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.^{5} H01Q 13/20, H01Q 13/22

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	H01Q 13/20, H01Q 13/22

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
A	WO,A1, 90/07201 (HUGHES AIRCRAFT COMPANY) 28 June 1990 (28.06.90) Figs 1(a) to 1(c) pages 5 to 8	
A	GB,A, 2221800 (ARIMURA GIKEN KABUSHIKI KAISHA) 14 February 1990 (14.02.90) Figs 1,7 to 11,13,16,17,19, pages 2-3	
A	GB,A, 2221799 (ARIMURA GIKEN KABUSHIKI KAISHA) 14 February 1990 (14.02.90) Figs 1 to 8,10,13 to 16, pages 2,4 to 11	
A	GB,A, 979645 (COMPAGNIE GENERALE DE TELEGRAPHIE SANS FIL) 6 January 1965 (06.01.65) Figs 1 to 3, pages 1-2	
A	US,A, 4112431 (WILD) 5 September 1978 (05.09.78) Figs 1 to 7, columns 1 to 5	
	(continued)	

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
3 July 1991 (03.07.91)	10 July 1991
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	PPGerondal P.P. GERONDAL

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	FR,B, 1291750 (COMPAGNIE GENERALE DE TELEGRAPHIE SANS FIL) 19 March 1962 (19.03.62) Figs 1 to 6, pages 1-2	

V. [ ] OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE 1

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.[ ] Claim numbers ..., because they relate to subject matter not required to be searched by this Authority, namely:

2.[ ] Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.[ ] Claim numbers ..., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4 (a):

VI. [ ] OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING 2

This International Searching Authority found multiple inventions in this international application as follows:

1.[ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.[ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.[ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. [ ] As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

[ ] The additional search fees were accompanied by applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL APPLICATION NO. PCT/AU 91/00165

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
GB 2221799	AU 39087/89 JP 2046006	CN 1040890	DE 3926187
GB 2221800	AU 39085/89 FR 2638025	CN 1040288 JP 2046004	DE 3926188
WO 9007201	CA 2003471 NO 903493	EP 404905	IL 92766
US 4112431	AU 14779/76	GB 1550387	

END OF ANNEX